A Structural Model of Locational Competition Among Gasoline Retailers: An Empirical Analysis

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Abstract

We propose a structural model to explain both the geographic locations of gasoline retailers in Singapore, as well as the nature of price competition between these retailers conditional on their geographic locations. Using empirical data on geographic locations and gasoline prices collected from the entire set of 226 gasoline stations in Singapore, and local market-level demographic data, we estimate the parameters of the proposed structural model of locational competition. Although market demand for gasoline are not observed, we are able to infer the effects of such demand on stations' location and pricing decisions using available data on local market-level demographics and equilibrium conditions of demand and supply. Using the estimates of our structural model, we answer counterfactual questions pertaining to station entry and exits on price competition between firms. Answering these questions has important policy implications for both the Singapore government and gasoline retailers in Singapore.

Keywords: Location Modeling, Networks, Discrete Locations, Price Competition, Gasoline Markets, P-Median Problems, Empirical Industrial Organization.

1 Introduction

Location is repeatedly stressed in the business press as one, if not the only, requirement for success in retailing. While this may be hyperbole, it is also recognized in the academic literature as being an important determinant of retail competition and performance. In fact, some of the earliest work on retail competition (e.g., Hotelling 1929, D'Aspremont, Gabszewicz and Thisse 1979) were based on models of spatial heterogeneity given the location decisions of retail firms. The literature has grown considerably since and we now have a variety of reconciliations for retailing practice and retailer performance. However, the vast majority of these tend to take the location decisions of retailers as given. For instance, Png and Reitman (1994) and Iyer and Seetharaman (2003b) address the puzzle of why retailers in the same geographic space adopt very similar strategies in certain instances and very different strategies in other cases assuming retail location decisions as exogenous. This paper attempts to understand the phenomenon of retail performance by developing a structural model of retail location and retail price competition. The simultaneous consideration of both location and marketing-mix interactions allows us to address a broader set of questions related to public policy as well as to provide a more comprehensive answer to questions of firm conduct and market performance. For example, we can now address questions such as

- What are the consequences of opening a new retail location (or closing an existing one) on the distribution of demand? What factors drive the re-distribution of demand?
- What is the role of location on the structure and mode of retail competition? Does this role vary across a market geography?
- Which of several existing locations for a given retail chain's stations in Singapore is the most profitable for the chain? Which are the least profitable?

The context for this paper is the gasoline market in Singapore. Gasoline is a good context for examining retail competition because it is a very good approximation to a homogenous product category. Consequently, similarities and/or dissimilarities in retail strategies cannot be rationalized on the basis of product differentiation. Singapore is a good geography for examining firm conduct because of institutional considerations.

1. It is a self-contained market of substantial size. For instance, 2002 petrol sales alone were in excess of a billion litres and, more infamously, Singapore ranks second (next to the U.S.) in global carbon dioxide emission per unit of GDP (Economist, May 9, 2003).

2. All the demand is supplied by local refiners and there is no possibility of supply-side leakage. Motorists crossing the borders into Malaysia (the only possible road transit) are required by-law to have their gas-tanks filled to at least three-quarters prior to crossing the border. Hence, supply-demand leakages due to the price differences between the two markets do not hold.[1]

3. The market is increasingly viewed as being a mature and competitive market. Gasoline demand is stable and expected to grow slowly due to the controlled increase in automobile ownership. Traditionally, retail competition was conducted through non-price instruments (sweepstakes, freebies, loyalty programs). Price promotions are a recent addition (past three to five years) to this mix and are becoming increasingly common and distributed across the entire island. Currently, upwards of 25% of gasoline stations are running promotions ranging in depth from 5% to 15% on petrol and/or diesel.

4. The oil majors control all elements of their channel from production to distribution to retailing. However, the location decisions for retail outlets are decided by the URA (Singapore's Urban Redevelopment Authority). The authority's view is that Singapore's supply capacity is in excess of demand and hence there is little need for new gasoline stations. In fact, the more pressing problem relates to the possible closure of some of the existing sites. This relates to sites which are near the end of their leases and others that are in close proximity to major new developmental projects (e.g., new commercial developments, mass transit projects, etc.)

Using a primary dataset - representing a census of all gasoline stations in Singapore -that tracks geographic locations, gasoline prices and various station characteristics across 227 gasoline stations, as well as the demographic characteristics of the stations' local neighborhoods, we

[1] The price differential between the two countries is substantial. The price of a liter of 98-octane petrol in May 2002 was 1.244 S$ in Singapore and 0.630 S$ in Malaysia (prices are in Singaporean dollars). The substantial gasoline tax revenues was suggested to the authors as one of reasons for the Singaporean ordinance.

undertake the estimation of a structural model of location and pricing decisions of gasoline stations.

The location model is built on the premise (which is consistent with institutional realities in Singapore, as discussed above) that the Singapore government determines where to locate gasoline stations in the city. The government, being a social welfare planner, is assumed to minimize aggregate travel costs incurred by consumers in their efforts to buy gasoline in Singapore. This leads to a location model that is called a *P-Median* problem, whose parameters are estimated using a minimum-distance estimator. Estimating the location model enables us to infer the geographic distribution of potential gasoline demand across local markets in Singapore, and the dependence of such local demand on local demographic characteristics.

We then propose a pricing model for gasoline stations, conditional on their chosen locations, based on the premise of Bertrand competition between firms. Two versions of this Bertrand pricing model are developed, one of which assumes that each gasoline station makes its own pricing decision, while the other assumes that gasoline retail chains make pricing decisions for all stations under their franchise. The pricing model requires not only local potential gasoline demand (which has been estimated in the location model) but also local firm-level demand as inputs. Since gasoline demand is unobserved in the data, we use equilibrium conditions of demand and supply to obtain an estimable model of pricing that circumvents the need to explicitly estimate a demand model. Estimating the pricing model allows us to infer both supply-side parameters - specifically firm-specific marginal costs and their dependence on station characteristics (such as number of gasoline pumps, presence of convenience store, and car-wash) - as well as demand-side parameters, i.e., the effects of station characteristics, geographic locations and prices on station-level demand. Using the estimates of the parameters of the location model and pricing model, we answer counterfactual questions pertaining to elimination of an existing stations or entry of a new station.

We estimate our proposed location model using empirical data on actual geographic locations of gasoline stations, and find that local potential gasoline demand depends positively on the following local demographic characteristics of the neighborhood: population, median income, number of cars, proximity to airport, downtown and highways. Using the estimated category-level demand at each local neighborhood in Singapore as an input, we then estimate our proposed pricing model using empirical data on actual prices of gasoline at various stations. We find retail margins for gasoline to be about 1-2%, and that market share for a gasoline station is positively influenced by gasoline price, geographic location of the station (i.e. proximity to dense neighborhoods of consumers), as well as the number of pumping bays.

2 Relationship to the Literature

The primary contribution of this paper is in developing a structural model for gasoline markets that simultaneously explains location and pricing decisions of gasoline stations. Shepard (1991) and Iyer and Seetharaman (2003a) estimate pricing models for gasoline stations that have local monopoly power. Their models are not applicable for competitive markets, as in this paper. Slade (1992) estimates a competitive pricing model using time-series data on demand and prices at 13 gasoline stations in the Greater Vancouver area. In focusing only on a limited number of firms in the same geographic neighborhood, the model ignores the role of location on competition. Iyer and Seetharaman (2003b) develop a competitive pricing model for gasoline markets that takes into account locational differences between stations, and then test the analytical implications of their pricing model at the market level using cross-sectional data from 246 stations in the Greater St. Louis area. Pinkse, Slade and Brett (2002) estimate a competitive pricing model that accommodates the effects of spatial locations of firms. However, both of these studies take a *reduced-form* approach to modeling the effects of location on price competition between firms. In contrast, we simultaneously propose and estimate a *structural* model of pricing behavior in this study, as in Manuszak (1999). Further, we believe that our paper is the first effort at modeling location decisions in gasoline markets. The institutional reality that the Singapore government serves as a social planner in determining locations of gasoline stations makes our location model both realistic and mathematically tractable. An alternative model of locational choices has been recently proposed by Seim (2002), who models geographic locations of video retailers.

The rest of the paper is organized as follows. In section 3 we develop empirical models to estimate location and pricing decisions of gasoline stations in Singapore, along with estimation techniques to estimate model parameters. In section 4 we describe our data. Section 5 presents the empirical results of our analyses. Along with the estimation results, we also answer counterfactual questions pertaining to new station entry in this section. Concluding remarks are made in Section 6.

3 Model of Location and Pricing Decisions of Gasoline Stations in Singapore

We present this section in eight parts. First, we set up some algebraic notation that is useful to follow our location model development. Second, we develop a canonical model of gasoline locational choices of gasoline stations. Third, we make explicit the parametric specification of the location model. Fourth, we discuss estimation details for the location model. Fifth, we set up some more algebraic notation that is useful to follow our pricing model development. Sixth, we develop a canonical model of gasoline pricing decisions conditional on the observed locational choices. Seventh, we present a specific parameterization of the pricing model. Eighth, we set up the estimation procedure for the pricing model.

3.1 Notation

To develop our model of locational choices of gasoline stations in the Singapore market, we first recognize that there are P gasoline stations in Singapore, where P has been determined by the Singapore government. We discretize the geographic map of Singapore into N grid points. At a given grid point i $(i = 1, 2, ..., N)$, there is assumed to be a level of potential gasoline demand q_i, which depends on such factors as local residential population, numbers of cars owned, income level, presence of highways, proximity to airport, downtown etc. In fact, we let Z_i be a vector of all relevant factors that explain potential gasoline demand, and rewrite the demand function as $q_i = q(Z_i; \alpha)$, where α is a vector of unknown parameters. Total potential gasoline demand in Singapore, therefore, is written as $Q = \sum_{i=1}^{N} q_i$.

We define X_j as an indicator variable that takes the value 1 if a gasoline station resides in grid point j and 0 otherwise. Suppose we define Y_{ij} as a binary outcome that takes the value 1 if consumers within grid point i choose the gasoline station in grid point j and 0 otherwise, then the total demand for the gasoline station in grid point j can be written as $Q_j = \sum_{i=1}^{N} q_i \cdot Y_{ij}$. One can allow Y_{ij} to depend, among other things, on the geographic distance d_{ij} between grid points i and j.

3.2 Location Model - Canonical Form

First, it is useful to note the following two features of the gasoline market in Singapore (that make it different from the gasoline market in the US):

1. Gasoline stations can only be built on specified plots determined by the government. Land is offered on a public tender in an open-bid system, and any company can bid.

2. Price competition among gasoline stations in Singapore is a relatively recent phenomenon. Prior to this, gasoline prices were determined on the basis of a multi-lateral agreement between the Singapore government and gasoline retailers. Therefore, prices were not only equal across stations, and were also assumed to be equal by the Singapore government while determining optimal locations for gasoline stations.

On account of the above two features of the Singapore gasoline market, we make the following two assumptions for our location model.

1. In empirically explaining observed locations of gasoline stations in Singapore, we assume that the Singapore government is the decision-maker.

2. Since gasoline prices are constant across gasoline stations, they do not play a role in the location model.[2]

   In addition, we make the following two assumptions:

3. The government picks geographic locations for the P gasoline stations so as to minimize the total expected travelling costs of all consumers in Singapore who constitute the total potential demand for gasoline.[3]

4. The supply capacity of each gasoline station exceeds its potential demand, i.e. an under-capacity problem does not exist.[4]

[2]Bidding decisions of oil companies will only determine *who* owns each location, and not *where* the locations themselves ought to be. This fact, coupled with our finding that the Singapore government sets up more gasoline stations in places with higher potential demand (which makes it worthwhile for firms to bid for such profitable locations), implies that firms' bidding decisions should not have an effect on the locational planning decisions of the Singapore government.

[3]This seems like a reasonable social welfare objective of the government.

[4]This was confirmed by managers of Exxon-Mobil, Shell and Caltex, three major oil companies in Singapore.

The Singapore government's problem is one of choosing P grid points, among the full set of N available grid points, to locate gasoline stations, in order to minimize the sum of travelling distances across all consumers who constitute potential gasoline demand. As mentioned earlier, let Y_{ij} denote a binary outcome that takes the value 1 if consumers within grid point i choose the gasoline station in grid point j and 0 otherwise. The Singapore government's objective function can then be written down as follows[5]:

$$\min_{X} \sum_{i=1}^{N} \sum_{j=1}^{N} q(Z_i; \alpha) d_{ij} Y_{ij} \tag{1}$$

$$\sum_{j=1}^{N} Y_{ij} = 1 \tag{2}$$

$$\sum_{j=1}^{N} X_j = P \tag{3}$$

$$Y_{ij} - X_j \leq 0, \ \forall i, j \tag{4}$$

$$Y_{ij} = 0 \ or \ 1 \tag{5}$$

$$X_j = 0 \ or \ 1 \tag{6}$$

where X_j, as mentioned earlier, is an indicator variable that takes the value 1 if a gasoline station resides in grid point j and 0 otherwise. Equation (1) is the objective function of the Singapore government. Equation (2) embodies the constraint that consumers within a grid point i can choose one and only one gasoline station. Equation (3) embodies the constraint that the government is working with P stations in its locational planning decision. Equation (4) captures the logical condition that consumers cannot choose to go to grid point j for their gasoline purchase if no gasoline station is located at j. Equation (5) implies that consumers at grid point i will choose either to travel to grid point j ($Y_{ij} = 1$) or not ($Y_{ij} = 0$). Finally,

[5] Our conversations with government planners indicate that models of this kind are routinely used in urban development.

equation (6) implies that a gasoline station is either set up at grid point j ($X_j = 1$) or not ($X_j = 0$).

Next, we specify the details of q_i, d_{ij} and the optimal decision for Y_{ij} and then discuss the estimation details.

3.3 Location Model - Parametric Specification

We specify potential gasoline demand at a grid point q_i using the following multiplicative model.

$$q_i = (\frac{POP_i}{POP_0})^{\alpha_1}(\frac{INC_i}{INC_0})^{\alpha_2}(\frac{CAR_i}{CAR_0})^{\alpha_3}\exp(\alpha_4 I_i^{AIR})\exp(\alpha_5 I_i^{DT})\exp(\alpha_6 I_i^{HWY}) \tag{7}$$

where POP_i is the residential population of grid point i, INC_i the median income of grid point i, CAR_i the total number of owned cars in grid point i, I_i^{AIR} is an indicator variable that takes the value 1 if grid point i is near the airport and 0 otherwise, I_i^{DT} is an indicator variable that takes the value 1 if grid point i is in the downtown area and 0 otherwise, and I_i^{HWY} is an indicator variable that takes the value 1 if grid point i is close to a highway and 0 otherwise. POP_0, INC_0, and CAR_0 are explanatory variables for a reference grid point, whose potential demand level q_0 is fixed at 1 (for identification purposes). Therefore, the explanatory variables for all other grid points are operationalized relative to the corresponding variables of this reference grid point.

The above-mentioned multiplicative model for potential gasoline demand at a grid point can be rewritten as the following linear model by taking logarithms of both sides of the multiplicative model.

$$\ln(q_i) = \alpha_1 \ln(\frac{POP_i}{POP_0}) + \alpha_2 \ln(\frac{INC_i}{INC_0}) + \alpha_3 \ln(\frac{CAR_i}{CAR_0}) + \alpha_4 I_i^{AIR_i} + \alpha_5 I_i^{DT_i} + \alpha_6 I_i^{HWY_i} \tag{8}$$

The geographic distance between grid points i and j, denoted by d_{ij}, is operationalized using the *Euclidean distance* measure[6]. In other words, suppose (x_i, y_i) and (x_j, y_j) are the Euclidean coordinates of i and j, then $d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$

The consumer's decision rule for choosing a gasoline station is specified as follows: Given all

[6]Using data from the New York State Department of Transportation, Phibbs and Luft (1995) find a correlation of 0.987 between straight-line distances and travel times. Other studies that use Euclidean distances as proxies for travel times include Manuszak (1999), Thomadsen (2001),Davis (2001), McManus (2003).

grid points k such that $X_k = 1$,

$$Y_{ij} = 1 \; iff \; d_{ij} = \min d_{ik} \tag{9}$$

In other words, consumers within a given grid point are assumed to choose the locationally closest gasoline station for their gasoline purchases. This makes perfect sense if prices are constant across all gasoline stations in Singapore (which was the case when the locational decisions being modeled here were made by the Singapore government).

3.4 Location Model - Estimation

The estimable parameters of the location model are captured in the vector $\alpha = (\alpha_1, ..., \alpha_6)$ that represents the parameters in the potential demand function q_i. We cast the location model in estimable econometric form as shown below.

$$X_j = \hat{X}_j(Z, P; \alpha^0) + e_j \tag{10}$$

where X_j is the *observed* location of station j, $\hat{X}_j(Z, P; \alpha^0)$ is the *predicted* (based on solving the objective of the Singapore government, as given in equation 1) location of station j, e_j stands for measurement error (with mean zero). Minimizing this measurement error in some manner, using an appropriate loss function, will serve as the estimation technique to recover estimates of α. It is useful to recognize here that X_j and $\hat{X}_j(Z, P; \alpha^0)$ are both two-dimensional variables since they represent station locations in two-dimensional Euclidean space.

The Singapore government's location problem, represented by equations 1-6 and called the *P-Median Problem*, can be solved using the *Lagrangian algorithm* (see Daskin 1995 for details)[7]. For a given α, therefore, one can compute the predicted locations $\hat{X}_j(Z, P; \alpha^0)$ using this algorithm. The estimation objective is to pick the value of α that minimizes the following *quasi* mean-squared error (QMSE).

$$QMSE(X, Z, P; \alpha) = \min_{\chi} \frac{1}{P} \sum_{j=1}^{P} \sum_{k=1}^{P} \sqrt{[X_j^{(x)} - \hat{X}_k^{(x)}(Z, P; \alpha)]^2 + [X_j^{(y)} - \hat{X}_k^{(y)}(Z, P; \alpha)]^2} \cdot \chi_{jk} \tag{11}$$

[7] The starting values are picked using the *Exchange algorithm*.

$$\sum_{j=1}^{P} \chi_{jk} = 1 \tag{12}$$

$$\sum_{k=1}^{P} \chi_{jk} = 1 \tag{13}$$

$$\chi_{jk} = 1 \; or \; 0 \; \forall \; j, k \tag{14}$$

where $X^{(x)}$ and $X^{(y)}$ denote the x- and y-coordinates of X respectively. The rationale of using χ_{jk} in the QMSE is as follows: After obtaining $\hat{X}$ by solving the P-median problem, one must pair up each of the P predicted locations with one of the P observed locations in the data before computing a mean-squared error. However, there are numerous ways of undertaking this pairing-up task. We pick the one that minimizes the mean-squared error. That is, among all possible pairings of locations in $\hat{X}$ and X, we pick the one that has minimum mean squared error. This is computationally achieved using the *Exchange* algorithm (see Daskin 1995 for details)[8].

The estimator for $\hat{\alpha}$ that we propose is that value that minimizes the QMSE. In other words,

$$\hat{\alpha} = \arg\min QMSE(X, Z, P; \alpha) \tag{15}$$

The rationale for this estimation algorithm is to employ an estimator that matches the observed and predicted station locations as closely as possible. In this sense, our proposed estimator is a *minimum distance* estimator, just like the *least squares* estimator. We use the Nelder-Mead (1965) non-derivative simplex method to search for $\hat{\alpha}$.

It is important to note that our location model specifies the potential gasoline demand at a grid point using all relevant demographic variables, such as local residential population, number of cars owned, median income etc. Previously proposed location models have used only local population to characterize potential local demand for a product (see, for example, Seim 2000). Our location model is also unique in that it captures the objectives of a social welfare maximizer, specifically the government, in determining retail locations.

[8]The starting values are picked using the *Myopic algorithm*.

3.5 Some More Notation

Before developing our model of pricing decisions of gasoline stations in the Singapore market, we set up some more notation here. P_j refers to the price of gasoline at station j, while Q_j refers to the demand for gasoline at station j. C_j refers to the marginal cost of selling gasoline at station j. We use Q_{ij} to refer to the demand in grid point i for gasoline at station j, S_{ij} to refer to the market share in grid point i for gasoline at station j, W_j to stand for a vector of station characteristics (number of pumping bays, pay-at-pump facility, presence of convenience store, specialty deli, service station, and car-wash) that are relevant in terms of influencing market share for gasoline at a station, V_j to stand for a vector of station characteristics (retail chain dummies) that are relevant in terms of influencing the marginal cost of procuring gasoline at a station.

3.6 Pricing Model - Canonical Form

Given relative locations of P gasoline stations, as determined by the Singapore government and represented using the location model discussed earlier, we next model gasoline prices at the P gasoline stations. There are six gasoline retail chains in Singapore: Shell, Caltex, Esso, Mobil, BP (British Petroleum) and SPC (Singapore Petroleum Company).[9]

We test two different pricing models, as explained below.

1. We assume that observed prices at P gasoline stations can be explained by solving for equilibrium prices that emerge from Bertrand competition between P gasoline stations.

2. We assume that observed prices at P gasoline stations can be explained by solving for equilibrium prices that emerge from Bertrand competition between the six gasoline retail chains, where each chain manager is assumed to set the price at each station belonging to his/her chain.

We will call the above two pricing models STOREMOD and CHAINMOD respectively.

[9]The merger of Exxon, called Esso in Singapore, with Mobil obviously reduces the number of independent chains in Singapore. However, at the time of data collection these stations retained their original identity. We retain this structure since it helps us illuminate better the brand specific effects on retail competition as also eases the exposition.

Under STOREMOD, a gasoline station's problem is one of choosing a gasoline price for its station in order to maximize the total variable profits from selling gasoline at that station. Station j's objective function can then be written down as follows:

$$\max_{P_j}[(P_j - C_j)Q_j] \tag{16}$$

The first-order conditions for gasoline station j under the STOREMOD maximization problem can then be written as follows.

$$Q_j + [(P_j - C_j)\frac{dQ_j}{dP_j}] = 0 \tag{17}$$

Under CHAINMOD, a gasoline retail chain's problem is one of choosing (possibly different) gasoline prices for all its stations in order to maximize the total variable profits from selling gasoline at all its stations. Retail chain n's objective function can then be written down as follows:

$$\max \sum_{P_j \forall\, j \text{ belongs to chain } n} [(P_j - C_j)Q_j] \tag{18}$$

The first-order conditions for gasoline station j (that belongs to retail chain n) under the CHAINMOD maximization problem can then be written as follows.

$$Q_j + \sum_{l \text{ belongs to chain } n} [(P_l - C_l)\frac{dQ_l}{dP_j}] = 0 \tag{19}$$

Next, we specify the parametric structure of Q_j and C_j and then discuss the estimation details.

3.7 Pricing Model - Parametric Specification

We specify demand for gasoline at station j, i.e. Q_j as follows.

$$Q_j = \sum_{i=1}^{N} Q_{ij} \tag{20}$$

where the demand in grid point i for gasoline at station j, i.e. Q_{ij}, is specified as follows.

$$Q_{ij} = S_{ij} q_i \tag{21}$$

where the market share in grid point i for gasoline at station j, i.e. S_{ij}, is specified as follows.

$$S_{ij} = \frac{e^{W_j\beta + d_{ij}\delta + P_j\gamma}}{1 + \sum_{k=1}^{P} e^{W_k\beta + d_{ik}\delta + P_k\gamma}} \tag{22}$$

where δ and γ stand for the travel cost and price sensitivity parameters of consumers respectively, β stands for a vector of parameters capturing the effects of station characteristics on gasoline demand at a station. This market-share model, also called the multinomial logit model, is consistent with random utility maximization on the part of individual consumers (McFadden 1974). The 1 in the denominator of the market-share model captures the effect of the outside good (i.e., consumers' option of not purchasing gasoline at any of the available gasoline stations, and choosing to travel by bus or taxi instead). The probabilistic choice rule of consumers that underlies the multinomial logit model is not necessarily inconsistent with the fixed choice rule determining Y_{ij} in the location model discussed earlier. This is because consumers were assumed to choose solely based on travel costs under the location model (i.e., under the assumption that price and all other relevant station characteristics are identical across stations). In such a case, the random utility model will reduce to a deterministic utility model based on travel costs only.

Under the conditions of the above market share model, consumers within a given grid point are assumed to allocate themselves between gasoline stations, taking two types of station characteristics into account (Iyer and Seetharaman 2003a, b): 1. horizontal characteristics (i.e. geographic locations, represented by d_{ij}), and 2. vertical characteristics (i.e. number of gasoline pumps, convenience store, car-wash and price, represented by W_j and P_j).

The marginal cost of firm j is specified as follows.

$$C_j = V_j\tau \tag{23}$$

where τ represents the effects of retail chain dummies on the marginal cost of gasoline at a station.

3.8 Pricing Model - Estimation

Plugging in equations (20) and (21) within equation (17) and simplifying yields the following first-order conditions for the STOREMOD pricing model.

$$\sum_{i=1}^{N} S_{ij} q_i + \gamma(P_j - C_j) \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i = 0 \tag{24}$$

which can be rewritten as follows.

$$P_j = C_j - \frac{\sum_{i=1}^{N} S_{ij} q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} \tag{25}$$

The above equation says that the price of gasoline at a station is equal to marginal cost plus a mark-up.

Plugging in equations (20) and (21) within equation (19) and simplifying yields the following first-order conditions for the CHAINMOD pricing model.

$$\sum_{i=1}^{N} S_{ij} q_i + \gamma(P_j - C_j) \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i - \sum_{l \textit{ belongs to chain } n, l \neq j} \gamma(P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i = 0 \tag{26}$$

which can be rewritten as follows.

$$P_j = C_j - \frac{\sum_{i=1}^{N} S_{ij} q_i - \sum_{l \textit{ belongs to chain } n, l \neq j} \gamma(P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} \tag{27}$$

The mark-up in the above equation is larger than that in equation (25), which is consistent with the retail chain's objective to maximize total profits across all its stores, and therefore picking higher prices to reduce cannibalization of gasoline sales across its own stores.

In equations (25) and (27), q_i is the predicted potential gasoline demand in grid point i (obtained using the estimates of the location model), S_{ij} is the market share at grid point i for station j, and γ is the price parameter in the market share model of equation (20). These equations will underlie the estimation of the demand parameters - β, δ, γ - in equation (22) and the supply parameters - τ - in equation (23).

The STOREMOD and CHAINMOD pricing models are nested within the following pricing model.

$$P_j = C_j - \frac{\sum_{i=1}^{N} S_{ij} q_i - \eta \sum_{l \textit{ belongs to chain } n, l \neq j} \gamma(P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} \tag{28}$$

where $\eta \in [0,1]$ is a *conduct* parameter that takes values not only to nest STOREMOD ($\eta = 0$) and CHAINMOD ($\eta = 1$) as special cases, but also allows for pricing models that lie on a continuum between these two pricing models ($\eta \in (0,1)$). We render this pricing model estimable by introducing measurement error as shown below.

$$P_j = C_j - \frac{\sum_{i=1}^{N} S_{ij} q_i - \eta \sum_{l \text{ belongs to chain } n, l \neq j} \gamma (P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} + \epsilon_j \tag{29}$$

where ϵ_j is assumed to be distributed iid $N(0, \sigma)$ across gasoline stations. We can further rewrite the above estimable equation as shown below.

$$\epsilon_j = P_j - C_j + \frac{\sum_{i=1}^{N} S_{ij} q_i - \eta \sum_{l \text{ belongs to chain } n, l \neq j} \gamma (P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} \tag{30}$$

which is an implicit equation involving prices P_j. Using the change-of-variable technique, we derive the distribution of prices, and then construct the sample likelihood function L based on this derived distribution for prices as shown below.

$$L = |J| \prod_{j=1}^{J} f(\epsilon_j) \tag{31}$$

where $f(.)$ is the univariate normal density evaluated for station j, and $|J|$ is the determinant of the Jacobian matrix J, whose elements are given by

$$\frac{\partial \epsilon_j}{\partial P_k} = I_{jk} + A_{jk} - B_{jk} \tag{32}$$

where I_{jk} is an indicator variable that takes the value 1 if $j = k$ and the value 0 otherwise, and

$$A_{jk} = \frac{\sum_{i=1}^{N} \frac{\partial S_{ij}}{\partial P_k} q_i - \eta \sum_{l \in n, l \neq j} \gamma (P_l - C_l) \sum_{i=1}^{N} (S_{il} \frac{\partial S_{ij}}{\partial P_k} + S_{ij} \frac{\partial S_{il}}{\partial P_k}) q_i}{\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i} \tag{33}$$

and

$$B_{jk} = \frac{[\gamma \sum_{i=1}^{N} (1 - 2S_{ij}) \frac{\partial S_{ij}}{\partial P_k} q_i][\sum_{i=1}^{N} S_{ij} q_i - \eta \sum_{l \in n, l \neq j} \gamma (P_l - C_l) \sum_{i=1}^{N} S_{il} S_{ij} q_i]}{[\gamma \sum_{i=1}^{N} S_{ij}(1 - S_{ij}) q_i]^2} \tag{34}$$

where

$$\frac{\partial S_{ij}}{\partial P_k} = \frac{-e^{W_j\beta + d_{ij}\delta + P_j\gamma}}{[1 + \sum_{l=1}^{P} e^{W_l\beta + d_{il}\delta + P_l\gamma}]^2} e^{W_k\beta + d_{ik}\delta + P_k\gamma}\gamma \tag{35}$$

and

$$\frac{\partial S_{ij}}{\partial P_j} = \frac{e^{W_j\beta + d_{ij}\delta + P_j\gamma}}{1 + \sum_{l=1}^{P} e^{W_l\beta + d_{il}\delta + P_l\gamma}} - \frac{e^{W_j\beta + d_{ij}\delta + P_j\gamma}}{[1 + \sum_{l=1}^{P} e^{W_l\beta + d_{il}\delta + P_l\gamma}]^2} e^{W_j\beta + d_{ij}\delta + P_j\gamma}\gamma \tag{36}$$

The sample likelihood function L in equation (31) is then maximized using the approximate gradient-based DFP algorithm to search for the optimal parameter estimates. Our pricing model is in the same spirit as Thomadsen (2001). However, while Thomadsen (2001) assumes potential gasoline demand at a grid point to be *exogenously* determined by the local population, we allow for potential gasoline demand at a grid point to be *endogenously* determined by local population, median income, number of cars owned, presence of highway and downtown (as estimated under the location model as discussed earlier)[10].

4 Description of Data

We employ survey data, representing a cross-section of 226 gasoline stations in Singapore during late 2001 and early 2002. Given in Figure 1 is the geographic map of Singapore. We include all gasoline stations in mainland Singapore in our empirical analyses, ignoring gasoline stations that are located in islands off the Singapore coast[11]. Among the 226 stations in mainland Singapore, 75 stations are owned by Shell, 43 by Mobil, 39 by Esso, 32 by Caltex, 29 by BP, and 8 by SPC. The survey data include, for each gasoline station, the prices of four grades - Premium, 98UL, 95UL and 92UL - of gasoline, the price of diesel, as well as a large number of station-specific characteristics, e.g. number of pumping bays, presence of convenience store, pay-at-pump facility, car wash, service station, ATM, store hours, prices of goods at convenience store etc. Our dataset also contains demographic information - population, home ownership, age, employment status, mode of transportation, income etc. - pertaining to each gasoline station's market. Three waves of data collection - all of which used the same survey instrument

[10]Unlike Thomadsen (2001), who uses the Generalized Method of Moments, we use the Maximum Likelihood Technique for estimation.

[11]There are a total of 229 gasoline stations in mainland Singapore. We had to exclude three stations - two belonging to Mobil and one to BP - whose geographic locations were missing in the survey data.

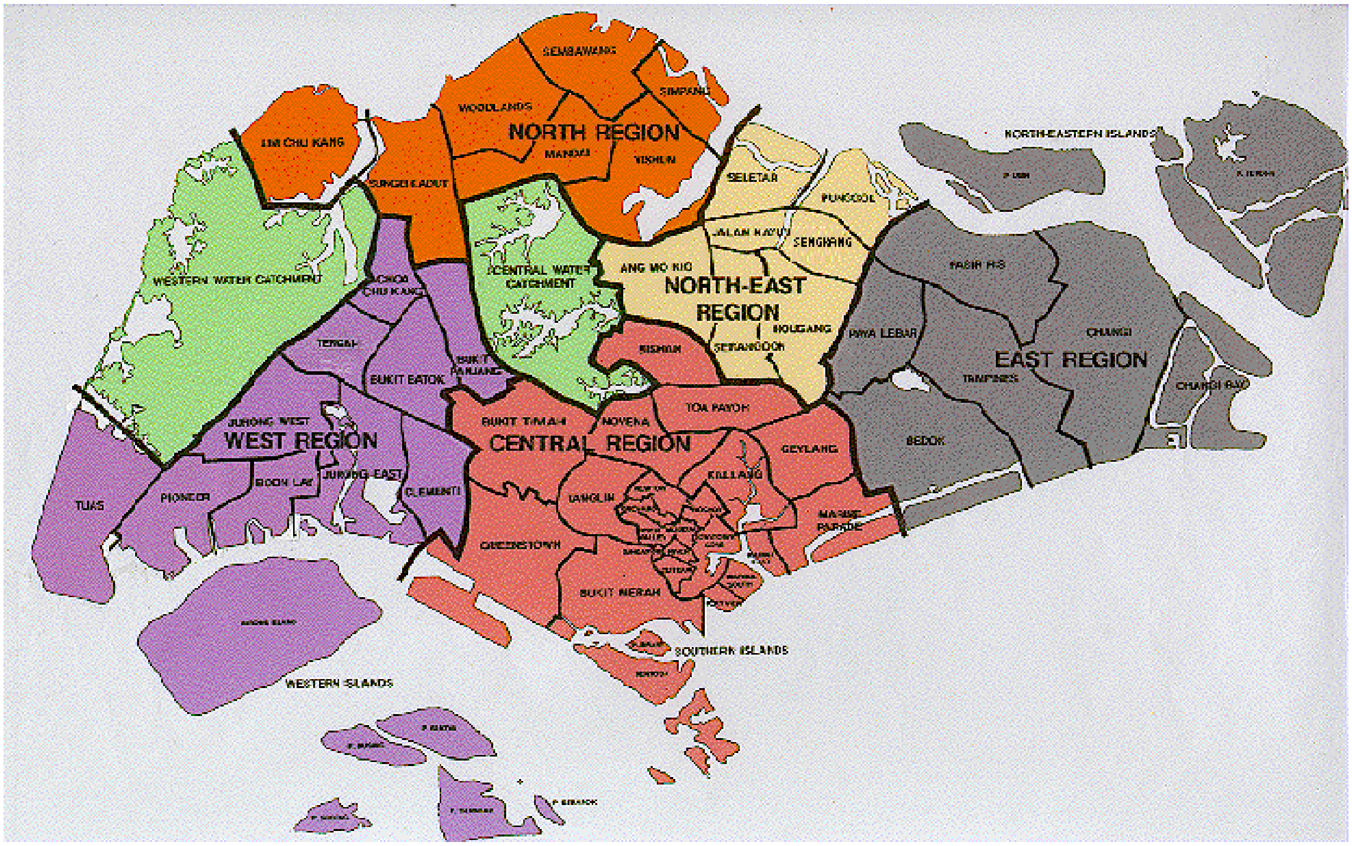

Figure 1: Geographic Map of Singapore

- were undertaken at the same set of 226 gasoline stations during the months of November 2001, December 2001 and January 2002. This yielded some time-series variation in gasoline prices. Among the 226 stations in our dataset, 107 sell premium petrol, 224 sell 98UL petrol, 213 sell 95UL petrol, and 165 sell 92UL petrol. Since 98UL is the most popular grade of gasoline in Singapore, we report the estimation results for our pricing model based on this grade of gasoline[12]. We pool the data across the three waves of data collection for estimation purposes. In the estimation, we include period-specific fixed effects in firms' marginal costs, restricted to be common across firms, in order to capture the effects of unobserved changes in wholesale prices of gasoline from period to period.

For the location model, we divide mainland Singapore into a rectangular grid of 1836 grid

[12] Estimation results for the other grades are consistent with those obtained for the 98UL grade, and are available from the authors.

points that are equally spaced both in the horizontal and vertical dimensions. Picking 1836 as opposed to a smaller number of grid points ensures that each grid point has no more than one gasoline station (if at all), which is required to be consistent with the canonical representation of our location model (see equations 1-6). Eliminating grid points that fall in the ocean and other uninhabited areas of Singapore leaves us with 1550 usable grid points for the estimation. Estimating the location model enables us to endogenously characterize potential gasoline demand at each grid point in Singapore (instead of restricting such demand to be proportional to local population). We allow the following demographic characteristics to influence local potential gasoline demand at each grid point (i.e. q_i).

1. POP_i: This stands for the local population represented within grid point i. It is computed as the ratio of the total population of the census tract to which the grid point belongs divided by the total number of grid points within that census tract.

2. INC_i: This stands for the median income of the census tract to which grid point i belongs.

3. CAR_i: This stands for the total number of cars represented within grid point i. It is computed as the ratio of the total number of cars within the census tract to which the grid point belongs divided by the total number of grid points within that census tract.

4. AIR_i: This is an indicator variable that takes the value 1 if grid point i is located adjacent to the airport, and 0 otherwise.

5. DT_i: This is an indicator variable that takes the value 1 if grid point i is located within the downtown area, and 0 otherwise.

6. HWY_i: This is an indicator variable that takes the value 1 if grid point i is located adjacent to a major highway, and 0 otherwise.

For the pricing model, we use the same set of 1550 grid points as in the location model in order to compute aggregate demand for each gasoline station (see equation 20). We also plug the estimated values of q_i from the location model directly into equation (21) while estimating the pricing model. We allow the following station characteristics to influence market shares for gasoline stations (i.e. S_{ij}). In other words, the following station characteristics together represent the vector W_j in equation 22.

1. $CHAIN_j$: This is a six-dimensional vector of indicator variables representing which of six different retail chains station j belongs to.

2. $PUMPS_j$: This stands for the total number of gasoline pumping bays available in station j.

3. PAY_j: This is an indicator variable that takes the value 1 if STATION j has pay-at-pump facility, and 0 otherwise.

4. $HOURS_j$: This is an indicator variable that takes the value 1 if station j is open 24 hours a day, and 0 otherwise.

5. $WASH_j$: This is an indicator variable that takes the value 1 if station j has a car wash facility, and 0 otherwise.

6. $SERV_j$: This is an indicator variable that takes the value 1 if station j has a service station, and 0 otherwise.

7. $DELI_j$: This is an indicator variable that takes the value 1 if station j has a specialty deli, and 0 otherwise.

The variable $PUMPS_j$ is observed to vary from 4 to 20 across stations in our dataset. The remaining indicator variables - PAY_j, $HOURS_j$, $WASH_j$, $SERV_j$ and $DELI_j$ - are observed to take the value 1 for 69, 88, 50, 52 and 22 percent of the stations in our dataset respectively. In addition to the above station characteristics, the market share model also includes the price of gasoline at station j, $PRICE_j$, as well as travel distance, d_{ij}, as explanatory variables (see equation 22). Retail chain dummies, as well as period dummies (capturing the second and third temporal waves of data collection) represent the vector V_j in equation 23. In other words, station characteristics other than retail chain identity - such as presence of car wash, service station etc. - are not expected to have an effect on the station's marginal cost of procuring gasoline.

Given in Table 1 are the means and standard deviations of prices of 98UL gasoline, the most popular grade of gasoline in Singapore, at various retail chains in Singapore. The average price of 98UL gasoline is about 5 cents lower at SPC compared to the other retail chains. The standard deviation of price of gasoline is about 0.03 cents (for most grades and retain chains), which is much smaller than the standard deviation of price observed in US markets (see, for example, Shepard 1991, Iyer and Seetharaman 2003a etc.).

Chain	*Mean*	*Std.Dev.*
Shell	1.19	0.03
Caltex	1.18	0.04
Esso	1.19	0.03
Exxon − Mobil	1.19	0.03
BP	1.19	0.03
SPC	1.14	0.03

Table 1: *Chain-Specific Means and Standard Deviations of 98UL Gasoline.*

5 Empirical Results

We report the estimates of our proposed location model (called PROPOS) in column 2 of Table 2 (the sampling intervals associated with these estimates, obtained using bootstrapping, are reported in Table 3 and are found to be quite narrow in width). The results show that, as expected, potential gasoline demand at a grid point is a positive function of the population, median income and number of cars owned in the local neighborhood. This validates our earlier contention that population is only one among several demographic variables that influence local demand for gasoline. We also find, as expected, that proximity to the airport, downtown and highways increase local potential gasoline demand, with proximity to highways accounting for the largest increase. All of these results are intuitively sensible and give excellent face validity to our proposed location model. We also estimate four benchmark models, the first of which ignores proximity to downtown, the second ignores proximity to both downtown and the airport, while the third and fourth simply use local population as the proxy for potential gasoline demand at a grid point. The difference between the third and fourth benchmark models is that the former estimates a parameter linking population to potential gasoline demand, while the latter restricts potential gasoline demand to be equal to the population. We call these models BENCH1, BENCH2, BENCH3 and BENCH4 respectively. The estimation results for these benchmark models are reported in columns 3-6 of Table 2. These results show that the estimated effect of each demographic variable is quite robust, in terms of its sign, across the various model specifications. In other words, the directional impact of each demographic variable on potential gasoline demand is insensitive to which other demographic variables are included in the location model. The estimated magnitudes of the parameters, however, show some variation from one specification to another. For example, it is clear from the results of the proposed location model and benchmark models 1-4 that restricting local potential gasoline demand to be exactly equal to the local population is not correct.

$Parameter$	$PROPOS$	$BENCH1$	$BENCH2$	$BENCH3$	$BENCH4$
POP_i	2.3425	3.7117	3.9270	1.7981	1
INC_i	2.5327	1.7257	0.8856	na	na
CAR_i	0.9462	1.0705	0.8995	na	na
AIR_i	1.8075	0.2751	na	na	na
DT_i	1.8394	na	na	na	na
HWY_i	2.9434	4.1596	3.7151	na	na

Table 2: *Estimated Parameters of the Location Model.*

$Parameter$	$10thPercentile$	$50thPercentile$	$90thPercentile$
POP_i	2.2442	2.3296	2.3732
INC_i	2.4368	2.5417	2.6293
CAR_i	0.9243	0.9573	0.9860
AIR_i	1.5610	1.8075	1.8925
DT_i	1.6186	1.7904	1.8394
HWY_i	2.8345	2.9306	3.0021

Table 3: *Bootstrapped Sampling Intervals for the Estimated Parameters of the Location Model.*

The estimated geographic locations, along with the actual geographic locations, of the 226 gasoline stations, are contained in Figure 2. Overall there appears to be a good degree of agreement between the locations generated on the basis of the social-welfare objective of the Singapore government (as in our proposed location model) and the actual locations of the 226 stations.

Figure 3 visually represents the estimated local potential gasoline demand across grid points on the Singapore map. Overlaying the distribution of potential gasoline demand across grid points on top of the distribution of gasoline stations across the same set of grid points enables us to visually convey the government's basis for placing large number of gasoline station locations

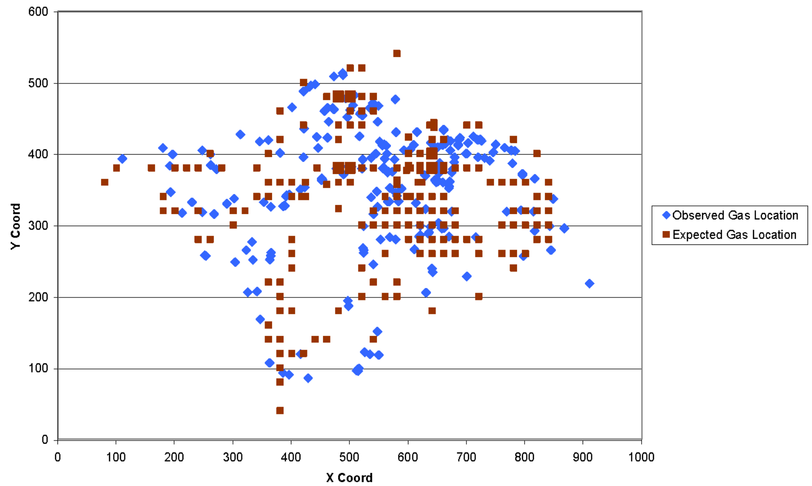

Figure 2: Estimated versus Observed Gasoline Station Locations

at some geographic neighborhoods and not at others. For example, the dense cluster of gasoline stations in the north-east portion of Figure 3, along with the estimated high degree of potential gasoline demand in this part of the map, is a consequence of three effects: the presence of downtown in the horizontal line spanning (380,380) to (620,380), the presence of the airport close to (700,350), and the presence of a major highway spanning the region (700,420) to (800,400).

In order to understand how well we are able to predict observed gasoline station locations using our chosen set of six demographic variables, we compare the predictive ability of our location model to that of the four benchmark models mentioned earlier. The fit statistics (i.e. quasi mean-squared error) for our proposed model as well as the four benchmark models are reported in Table 4. It is clear that our proposed location model significantly reduces the predictive error of estimation compared to the benchmark models, with the reduction being fairly substantial from BENCH3 and BENCH4.

Model	*QMSE*
PROPOSED MODEL	7210
BENCHMARK MODEL 1	8465
BENCHMARK MODEL 2	8599
BENCHMARK MODEL 3	13586
BENCHMARK MODEL 4	15199

Table 4: *Quasi Mean-Squared Error (QMSE) Statistics for the Proposed Location Model versus the Benchmark Location Models.*

Given in Table 5 is the estimate of the conduct parameter η, which measures the point on the continuum between STOREMOD and CHAINMOD where the observed prices in our dataset lie. Since the estimated value of η is not significantly different from zero, we conclude that STOREMOD characterizes the observed price data.

Parameter	*Estimate*	Standard Error
η	0.000	0.000

Table 5: *Estimate of Conduct Parameter.*

Next in Table 6 we present the results of the STOREMOD pricing model for 98UL gasoline. The estimated marginal costs of 98UL gasoline in the first wave is about \$1.22 per liter, while the multipliers for the second and third waves are 0.9506 and 0.9505 respectively, which renders

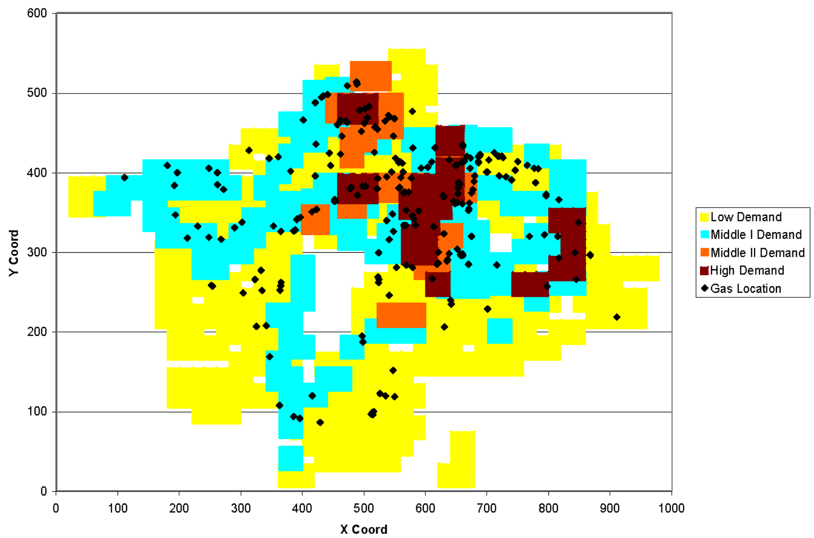

Figure 3: Estimated Potential Gasoline Demand

the estimated marginal costs of 98UL gasoline in the second and third waves to be about $1.16 per liter. This means that the estimated retail margins for gasoline are only about 1-2 %, which indicates that the gasoline market in Singapore is very price competitive. The estimated marginal cost of 98UL gasoline is about 5 cents lower at SPC than at other retail chains, which is consistent with the lower prices observed in SPC stations (see Table 1). Our conversations with managers, academics and civil servants in Singapore suggest at least two reasons for this result. First, SPC by virtue of being a local company (and being the smallest firm in this market) has the lowest overheads. Second, SPC has lower costs due to a different input mix for its refinery (with concomitant lower applicable tax rates as well).

Baseline market shares are found to be similar across the six different retail chains, as reflected in the estimated chain-specific intercepts in the market share model[13]. The coefficients associated with both price and travel distance are negative and significant (-422.4312 and -2.8983 respectively). This implies that both price and travel distance are important considerations for consumers when they choose between gasoline stations, which is intuitively pleasing since this underscores the importance of locations in firms' pricing decisions. All the station characteristics are observed to have a positive effect on station-level demand for 98UL gasoline. However, only the coefficient associated with number of pumps is found to be statistically significant. Our finding about the importance of number of pumps in influencing station demand is consistent with the findings in Png and Reitman (1994)[14].

[13]None of the six estimates is significantly different from zero.

[14]The substantive nature of the pricing model results (i.e. signs of parameter estimates) were observed to be very similar for the 95UL grade of gasoline. Those results are available from the authors.

$Parameter$	$Estimate$	$Std.Error$
$COST1_{Shell}$	1.2294	0.0286
$COST1_{Caltex}$	1.2207	0.0410
$COST1_{Esso}$	1.2299	0.0356
$COST1_{Mobil}$	1.2280	0.0347
$COST1_{BP}$	1.2322	0.0395
$COST1_{SPC}$	1.1812	0.0880
$MULT_{Wave2}$	0.9506	0.0996
$MULT_{Wave3}$	0.9505	0.0992
$CHAIN_{Shell}$	0.0331	0.4347
$CHAIN_{Caltex}$	0.0452	0.4432
$CHAIN_{Esso}$	0.0976	0.2143
$CHAIN_{Mobil}$	0.0104	0.4147
$CHAIN_{BP}$	0.0637	0.2018
$CHAIN_{SPC}$	0.0391	0.4736
$PUMPS_j$	0.3033	0.1191
PAY_j	0.5679	0.7251
$HOURS_j$	0.8292	0.7381
$WASH_j$	0.1180	0.2496
$SERV_j$	0.2287	0.5707
$DELI_j$	0.1668	0.5818
$PRICE_j$	-422.4319	10.5772
d_{ij}	-2.8983	0.0849

Table 6: *Estimated Parameters of the STOREMOD Pricing Model.*

6 Policy Implications

6.1 Equivalent Price Discounts

In order to understand the substantive implications of our estimation results, we interpret the coefficients associated with station characteristics (based on the results for 98UL gasoline) in terms of equivalent price discounts, i.e. the price discount on gasoline that will produce an equivalent increase in utility to a consumer for the station. The equivalent price discount for the presence of an additional pump in the station is 0.07 cents per liter of gasoline. The corresponding discounts for the presence of pay-at-pump, 24-hour service, car-wash, service station and deli are 0.13 cents, 0.20 cents, 0.03 cents, 0.05 cents and 0.04 cents per liter respectively. We interpret the travel cost parameter in similar terms. We find that consumers will be willing to travel up to 0.28 km (0.17 miles) to save 5 cents per liter of gasoline.

6.2 Equilibrium Prices and Profits

Based on the estimated parameters, we compute the equilibrium prices of all the gasoline stations in our dataset[15]. Based on the assumption that the 351553 owned cars in Singapore are allocated across the 1150 demand points in direct proportion to the estimated values of q_i from the location model, and the assumption that each car uses 40 liters of gasoline per week, we generate equilibrium sales, and hence revenues and profits, for each station in our dataset. The results of these analyses are reported in Table 7. Among the 75 Shell stations, the most profitable station is estimated to be the one at (910, 218) with an estimated profit of $232 per week. Among the 30 Caltex stations, the most profitable station is estimated to be the one at (192.5, 346) with an estimated profit of $235 per week. Among the 39 Esso stations, the most profitable station is estimated to be the one at (415, 119) with an estimated profit of $208 per week. Among the 43 Mobil stations, the most profitable station is estimated to be the one at (179.5, 408) with an estimated profit of $240 per week. Among the 29 BP stations, the most profitable station is estimated to be the one at (196, 399) with an estimated profit of $233 per week. Among the 8 SPC stations, the most profitable station is estimated to be the one at (110, 393) with an estimated profit of $266 per week. The total (i.e. summed across all stations belonging to each chain) weekly profits of Shell, Caltex, Esso, Mobil, BP and SPC are $11031, $4561, $5848,

[15] We use the estimated marginal costs for the first wave.

\$6468, \$4179 and \$1361 respectively. The corresponding weekly revenues are \$5.7 mil., \$2.3 mil., \$3.0 mil., \$3.3 mil., \$2.2 mil. and \$0.7 mil. respectively. Clearly, therefore, Shell has the dominant share of the Singapore gasoline market. In Figure 3, we show the geographic locations of these stations as well the geographic distribution of each chain's stations on the Singapore map.

Characteristic	*Shell*	*Caltex*	*Esso*	*Mobil*	*BP*	*SPC*
X-coordinate	910	192.5	415	179.5	196	110
Y-coordinate	218	346	119	408	399	393
$PUMPS_j$	4	12	18	10	8	8
PAY_j	1	0	1	1	1	0
$HOURS_j$	0	1	1	1	1	0
$WASH_j$	0	1	1	1	0	1
$SERV_j$	0	0	0	0	1	1
$DELI_j$	0	0	1	0	0	0
$PRICE_j$	\$1.234	\$1.234	\$1.234	\$1.234	\$1.234	\$1.234
$\hat{PRICE}_j$	\$1.232	\$1.223	\$1.232	\$1.230	\$1.235	\$1.184
$\hat{SALES}_j$	97425 l	98852 l	87721 l	100894 l	98126 l	111776 l
$\hat{REVENUES}_j$	\$120015	\$120909	\$108104	\$124138	\$121149	\$132297
$\hat{PROFITS}_j$	\$232	\$235	\$208	\$240	\$233	\$266

Table 7: *Station Characteristics for the Most Profitable Stations within the Six Retail Chains.*

For each of the six retail chains, we also identify the worst performing station in Singapore in terms of the predicted equilibrium profits. These stations can be ideal candidates for withdrawal from the market (unless the poor performance in gasoline is made up for by revenues from other products such as car wash, convenience store etc.[16]). We find that the worst Shell station is the one at (576, 392), the worst Caltex station is the one at (627.5, 370), the worst Esso station is the one at (565, 375), the worst Mobil station is the one at (564, 373.5), the worst BP station is the one at (572, 374.5), and the worst SPC station is the one at (476, 379). It is interesting to note that the least profitable stations are located in the densest neighborhood in Singapore in terms of potential gasoline demand, which suggests that competitive pressures are dissipating the profitability of these stations[17].

[16]In other words, gasoline may be serving as a *loss-leader* at these stores in order to drive sales of ancillary products and services.

[17]Our conversations with retail chain managers in Singapore suggest that stations that are currently being considered for closing down are located in this neighborhood. This nicely corroborates our empirical findings.

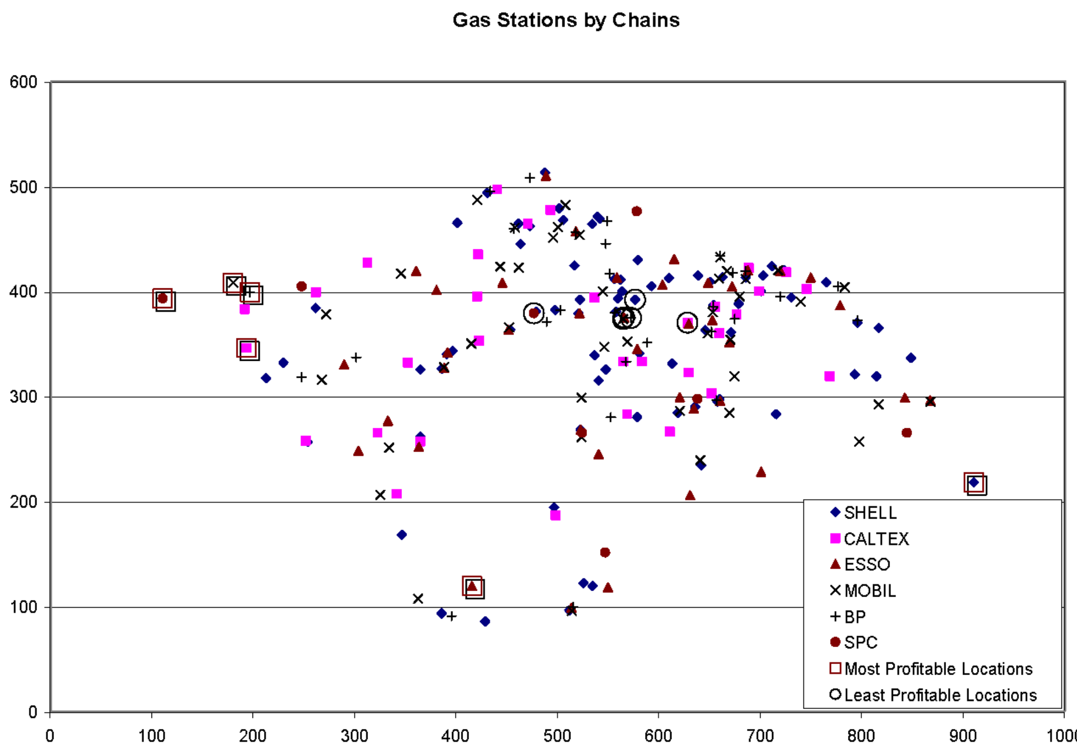

Figure 4: Geographic Distribution of Gasoline Stations by Chain (Most Profitable Stations Indicated within Boxes, Least Profitable Stations Indicated within Circles)

6.3 Station Exits in a Local Pentapoly

Next we consider a local market with five gasoline stations, two of which belong to Shell, and one each to Esso, Mobil and BP. The spatial coordinates of these five stations, along with their retail characteristics, are given in Table 8. The spatial locations of these stations are given in Figure 4. 98UL gasoline is currently priced at \$1.234 per liter at all of these stations. Note that Mobil is the biggest station in this pod (highest sales, largest number of pumping bays, etc.). Tables 9-13 provide the equilibrium prices, sales, revenues and profits for the 5 scenarios when each of these five stations are assumed to be closed one at a time. Obviously, sales of the remaining set of four stations always improve with the closure of the fifth station. However, the Mobil station is able to command the highest increases in unit sales (between 0.5% to 1%) when any of the other four competitors close, and also, the highest increases in revenues (between 0.4% and 1%). It does not show the highest increases in percentage change in sales but that is due to the fact that it has the largest sales in the pod to begin with. This result is similar to the double jeopardy results in the price promotion literature. Given that the popular wisdom in Singapore currently is that there is an over-supply of gasoline stations, counterfactual experiments of this kind will be enormously useful to policy makers investigating the consequences of closing down existing stations in Singapore. Our analysis can also be used by the oil majors to explore the consequences of closure of some of their stations. Recall that there are two Shell stations in this pod. If Shell had to close one of these, which one should it be? The answer is not obvious since the two stations are similar in most respects (the differences are that Shell1 has two more pumps than Shell2 and has a car-wash that Shell2 does not, while Shell2 has a service station that Shell1 does not). Further, the competitive responses from nearby stations to a station exit, both in terms of pricing changes and consequent demand shifting between stations, needs to be considered as well. Our results show that Shell is better off closing Shell2 as opposed to Shell1. Given the similarity in station characteristics, this result is a reflection of the better locational endowments of Shell1 relative to Shell2.

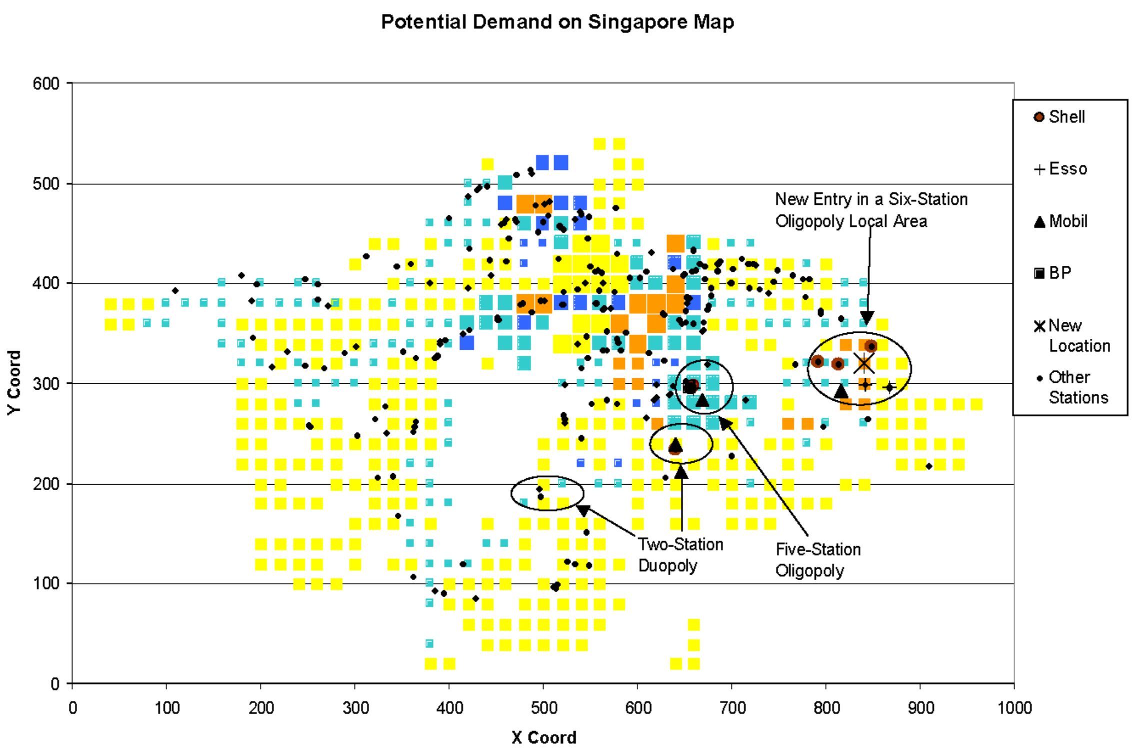

Figure 5: Geographic Locations of Chosen Local Oligopolies for Exit Simulations

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
X-coordinate	657	659	660	669	656
Y-coordinate	295	297	295.5	284	296
$PUMPS_j$	12	10	12	14	8
PAY_j	1	1	0	1	1
$HOURS_j$	1	1	1	1	1
$WASH_j$	1	0	1	1	1
$SERV_j$	0	1	1	1	0
$DELI_j$	0	0	0	1	0
$PRICE_j$	\$1.234	\$1.234	\$1.234	\$1.234	\$1.234
$\hat{PRICE}_j$	\$1.232	\$1.232	\$1.232	\$1.230	\$1.235
$\hat{SALES}_j$	56978 l	56957 l	57213 l	59215 l	56920 l
$\hat{REVENUES}_j$	\$70189	\$70163	\$70507	\$72856	\$70275
$\hat{PROFITS}_j$	\$135	\$135	\$136	\$140	\$135

Table 8: *Station Characteristics for a Local Five-Station Oligopoly.*

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
$\hat{PRICE}_j$	na	\$1.232	\$1.232	\$1.230	\$1.235
$\hat{SALES}_j$	na	57196 l	57453 l	59463 l	57159 l
$\hat{REVENUES}_j$	na	\$70457	\$70803	\$73162	\$70569
$\hat{PROFITS}_j$	na	\$136	\$137	\$141	\$136
$\Delta\hat{REVENUES}_j$	na	\$294	\$294	\$306	\$294
$\Delta\hat{PROFITS}_j$	na	\$1	\$1	\$1	\$1

Table 9: *Equilibrium Predictions after Assumed Exit of Shell1 from the Local Market.*

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
$\hat{PRICE}_j$	\$1.232	na	\$1.232	\$1.230	\$1.235
$\hat{SALES}_j$	57217 l	na	57453 l	59463 l	57159 l
$\hat{REVENUES}_j$	\$70484	na	\$70803	\$73162	\$70569
$\hat{PROFITS}_j$	\$136	na	\$137	\$141	\$136
$\Delta\hat{REVENUES}_j$	\$295	na	\$296	\$306	\$294
$\Delta\hat{PROFITS}_j$	\$1	na	\$1	\$1	\$1

Table 10: *Equilibrium Predictions after Assumed Exit of Shell2 from the Local Market.*

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
$P\hat{RICE}_j$	\$1.232	\$1.232	na	\$1.230	\$1.235
$S\hat{ALES}_j$	57218 l	57197 l	na	59464 l	57160 l
$REV\hat{ENUES}_j$	\$70485	\$70459	na	\$73163	\$70570
$PRO\hat{FITS}_j$	\$136	\$136	na	\$141	\$136
$\Delta REV\hat{ENUES}_j$	\$296	\$296	na	\$307	\$295
$\Delta PR\hat{OFITS}_j$	\$1	\$1	na	\$1	\$1

Table 11: *Equilibrium Predictions after Assumed Exit of Esso from the Local Market.*

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
$P\hat{RICE}_j$	\$1.232	\$1.232	\$1.232	na	\$1.235
$S\hat{ALES}_j$	57227 l	57205 l	57463 l	na	57168 l
$REV\hat{ENUES}_j$	\$70495	\$70469	\$70815	na	\$70581
$PRO\hat{FITS}_j$	\$136	\$136	\$137	na	\$136
$\Delta REV\hat{ENUES}_j$	\$306	\$306	\$308	na	\$306
$\Delta PR\hat{OFITS}_j$	\$1	\$1	\$1	na	\$1

Table 12: *Equilibrium Predictions after Assumed Exit of Mobil from the Local Market.*

$Characteristic$	$Shell1$	$Shell2$	$Esso$	$Mobil$	BP
$P\hat{RICE}_j$	\$1.232	\$1.232	\$1.232	\$1.230	na
$S\hat{ALES}_j$	57212 l	57190 l	57448 l	59457 l	na
$REV\hat{ENUES}_j$	\$70477	\$70450	\$70797	\$73155	na
$PRO\hat{FITS}_j$	\$136	\$136	\$137	\$141	na
$\Delta REV\hat{ENUES}_j$	\$288	\$287	\$290	\$299	na
$\Delta PR\hat{OFITS}_j$	\$1	\$1	\$1	\$1	na

Table 13: *Equilibrium Predictions after Assumed Exit of BP from the Local Market.*

6.4 Station Exits in a Local Duopoly

6.4.1 Duopoly One

Now we consider a local market with two gasoline stations, one of which belongs to Shell, and the other belongs to Mobil. The spatial coordinates of these two stations, along with their retail characteristics, are given in Table 14. The spatial locations of these stations are given in Figure 4. 98UL gasoline is currently priced at \$1.234 per liter at both of these stations. The Shell station is slightly larger than the Mobil station in terms of equilibrium sales and profits. Tables 15-16 provide the equilibrium prices, sales, revenues and profits for the two scenarios when each of these stations is assumed to be closed one at a time. It is observed that both stations gain the same in absolute terms - either on a revenue criterion or on a profit criterion - when the other station exits the market. However, since the Mobil station is slightly smaller, it gains more in relative terms out of the closure of the Shell station than what Shell gains out of the closure of the Mobil station.

Characteristic	*Shell*	*Mobil*
X-coordinate	641	640
Y-coordinate	234	239
$PUMPS_j$	8	12
PAY_j	1	1
$HOURS_j$	1	1
$WASH_j$	0	0
$SERV_j$	1	0
$DELI_j$	0	1
$PRICE_j$	\$1.234	\$1.234
$PR\hat{I}CE_j$	\$1.232	\$1.230
$SA\hat{L}ES_j$	63980 l	63093 l
$REVE\hat{N}UES_j$	\$78814	\$77628
$PRO\hat{F}ITS_j$	\$152	\$150

Table 14: *Station Characteristics for a Local Duopoly.*

$Characteristic$	$Mobil$
$P\hat{RICE}_j$	\$1.230
$SA\hat{L}ES_j$	63388 l
$REVE\hat{N}UES_j$	\$77991
$PRO\hat{F}ITS_j$	\$151
$\Delta REV\hat{E}NUES_j$	\$363
$\Delta PR\hat{O}FITS_j$	\$1

Table 15: *Equilibrium Predictions after Assumed Exit of Shell from the Local Market.*

$Characteristic$	$Shell$
$P\hat{RICE}_j$	\$1.232
$SA\hat{L}ES_j$	64274 l
$REVE\hat{N}UES_j$	\$79177
$PRO\hat{F}ITS_j$	\$153
$\Delta REV\hat{E}NUES_j$	\$363
$\Delta PR\hat{O}FITS_j$	\$1

Table 16: *Equilibrium Predictions after Assumed Exit of Mobil from the Local Market.*

6.4.2 Duopoly Two

Next we consider another local market with two gasoline stations, one of which belongs to Shell, and the other belongs to Caltex. The spatial coordinates of these two stations, along with their retail characteristics, are given in Table 17. The spatial locations of these stations are given in Figure 4. 98UL gasoline is currently priced at $1.234 per liter at both of these stations. The Caltex station is slightly larger than the Shell station in terms of equilibrium sales and profits. Tables 18-19 provide the equilibrium prices, sales, revenues and profits for the two scenarios when each of these stations is assumed to be closed one at a time. We find that the smaller Shell station gains more, both in relative and absolute terms, out of the closure of the Caltex station than what Caltex gains out of the closure of the Shell station. The potential gains for a station from the exit of the other station are observed to be higher in this duopoly compared to the duopoly considered in the earlier sub-section,. This is not surprising considering that this is a more profitable duopoly to begin with.

Characteristic	*Shell*	*Caltex*
X-coordinate	496	497.5
Y-coordinate	194	186.5
$PUMPS_j$	8	4
PAY_j	1	1
$HOURS_j$	1	0
$WASH_j$	0	0
$SERV_j$	1	1
$DELI_j$	0	0
$PRICE_j$	$1.234	$1.234
$PR\hat{I}CE_j$	$1.232	$1.223
$SA\hat{L}ES_j$	70960 l	71907 l
$REVE\hat{N}UES_j$	$87413	$87951
$PRO\hat{F}ITS_j$	$169	$171

Table 17: *Station Characteristics for a Local Duopoly.*

$Characteristic$	$Caltex$
$P\hat{RIC}E_j$	\$1.223
$SA\hat{L}ES_j$	72274 l
$REVE\hat{N}UES_j$	\$88401
$PRO\hat{F}ITS_j$	\$172
$\Delta REV\hat{E}NUES_j$	\$450
$\Delta PR\hat{O}FITS_j$	\$1

Table 18: *Equilibrium Predictions after Assumed Exit of Shell from the Local Market.*

$Characteristic$	$Shell$
$P\hat{RIC}E_j$	\$1.232
$SA\hat{L}ES_j$	71328 l
$REVE\hat{N}UES_j$	\$87866
$PRO\hat{F}ITS_j$	\$170
$\Delta REV\hat{E}NUES_j$	\$453
$\Delta PR\hat{O}FITS_j$	\$1

Table 19: *Equilibrium Predictions after Assumed Exit of Caltex from the Local Market.*

6.5 New Station Entry

Using the estimates of our location model, we predict the best location for a new gasoline station from the standpoint of the Singapore government minimizing consumer travel costs. The optimal location is found to be at (840,320) (see Figure 5). We then compute the equilibrium profits that can be obtained by the six retail chains from successfully bidding for and obtaining this new location for a gasoline station belonging to their chain[18]. We also compute resulting equilibrium profits of the six gasoline stations that are in the vicinity of this location in order to determine possible cannibalization of profits within the same chain. The characteristics of the six neighborhood stations are reported in Table 17, while the equilibrium predictions based on the various entry assumptions are reported in Tables 18-23. It can be observed that BP stands to gain more by introducing a new station at (840,320), not only because it will incur higher profits than other retain chains at this location (comparing the profits in Table 22 to the profits in Tables 18-21 and Table 23), but also because it does not have any physical presence in that geographic neighborhood, which means that there are no potential cannibalization concerns. For similar reasons, Shell, that has the most prominent local presence in this neighborhood (with three existing stations), stands the most to lose in terms of cannibalizing its own chain sales by introducing a fourth station at (840,320).

[18] We assume the new station to have $PUMPS = 12, PAY = 1, HOURS = 1, WASH = 1, SERV = 0, DELI = 0$.

$Characteristic$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
X-coordinate	848	814	792.5	867	842	816
Y-coordinate	336.5	319	321	296	298.5	292
$PUMPS_j$	12	12	10	8	18	14
PAY_j	1	1	1	0	1	1
$HOURS_j$	1	1	1	1	1	1
$WASH_j$	0	1	1	0	1	1
$SERV_j$	0	1	0	0	0	0
$DELI_j$	0	0	0	1	1	1
$PRICE_j$	\$1.234	\$1.234	\$1.234	\$1.234	\$1.234	\$1.234
$\hat{PRICE}_j$	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	80355 l	75568 l	72275 l	85229 l	80821 l	77276 l
$\hat{REVENUES}_j$	\$98987	\$93089	\$89033	\$105034	\$99601	\$95079
$\hat{PROFITS}_j$	\$191	\$180	\$172	\$203	\$192	\$184

Table 20: *Station Characteristics for the Six Stations Close to the New Station Location.*

$Characteristic$	$ShellNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	79105 l	79881 l	75121 l	71849 l	84726 l	80344 l	76820 l
$\hat{REVENUES}_j$	\$97447	\$98403	\$92540	\$88508	\$104414	\$99013	\$94518
$\hat{PROFITS}_j$	\$188	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta\hat{REVENUES}_j$	\$97447	-\$584	-\$549	-\$525	-\$620	-\$588	-\$561
$\Delta\hat{PROFITS}_j$	\$188	-\$1	-\$1	-\$1	-\$1	-\$1	-\$1

Table 21: *Equilibrium Predictions Based on the Assumption that the New Station belongs to Shell.*

$Characteristic$	$CaltNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.223	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	78885 l	79882 l	75123 l	71850 l	84728 l	80345 l	76821 l
$\hat{REVENUES}_j$	\$96486	\$98404	\$92541	\$88509	\$104416	\$99015	\$94519
$\hat{PROFITS}_j$	\$187	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta\hat{REVENUES}_j$	\$96486	-\$583	-\$548	-\$524	-\$618	-\$586	-\$560
$\Delta\hat{PROFITS}_j$	\$187	-\$1	-\$1	-\$1	+\$1	-\$1	-\$1

Table 22: *Equilibrium Predictions Based on the Assumption that the New Station belongs to Caltex.*

$Characteristic$	$EssoNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	79114 l	79881 l	75121 l	71849 l	84726 l	80344 l	76820 l
$\hat{REVENUES}_j$	\$97498	\$98403	\$92540	\$88508	\$104414	\$99013	\$94518
$\hat{PROFITS}_j$	\$188	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta \hat{REVENUES}_j$	\$97498	-\$584	-\$548	-\$525	-\$620	-\$588	-\$561
$\Delta \hat{PROFITS}_j$	\$188	-\$1	-\$1	-\$1	+\$1	-\$1	-\$1

Table 23: *Equilibrium Predictions Based on the Assumption that the New Station belongs to Esso.*

$Characteristic$	$MobilNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.230	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	79069 l	79881 l	75122 l	71849 l	84727 l	80344 l	76820 l
$\hat{REVENUES}_j$	\$97285	\$98403	\$92540	\$88508	\$104415	\$99013	\$94518
$\hat{PROFITS}_j$	\$188	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta \hat{REVENUES}_j$	\$97285	-\$584	-\$548	-\$525	-\$619	-\$588	-\$561
$\Delta \hat{PROFITS}_j$	\$188	-\$1	-\$1	-\$1	+\$1	-\$1	-\$1

Table 24: *Equilibrium Predictions Based on the Assumption that the New Station belongs to Mobil.*

$Characteristic$	$BPNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.235	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	79173 l	79880 l	75121 l	71848 l	84726 l	80343 l	76820 l
$\hat{REVENUES}_j$	\$97749	\$98402	\$92539	\$88508	\$104414	\$99013	\$94517
$\hat{PROFITS}_j$	\$188	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta \hat{REVENUES}_j$	\$97749	-\$585	-\$549	-\$525	-\$620	-\$588	-\$562
$\Delta \hat{PROFITS}_j$	\$188	-\$1	-\$1	-\$1	+\$1	-\$1	-\$1

Table 25: *Equilibrium Predictions Based on the Assumption that the New Station belongs to BP.*

$Characteristic$	$SPCNew$	$Shell1$	$Shell2$	$Shell3$	$Esso1$	$Esso2$	$Mobil$
$\hat{PRICE}_j$	\$1.184	\$1.232	\$1.232	\$1.232	\$1.232	\$1.232	\$1.230
$\hat{SALES}_j$	77889 l	79888 l	75128 l	71855 l	84734 l	80351 l	76827 l
$\hat{REVENUES}_j$	\$92188	\$98411	\$92548	\$88516	\$104423	\$99022	\$94526
$\hat{PROFITS}_j$	\$185	\$190	\$179	\$171	\$202	\$191	\$183
$\Delta \hat{REVENUES}_j$	\$92188	-\$576	-\$540	-\$519	-\$611	-\$579	-\$553
$\Delta \hat{PROFITS}_j$	\$185	-\$1	-\$1	-\$1	+\$1	-\$1	-\$1

Table 26: *Equilibrium Predictions Based on the Assumption that the New Station belongs to SPC.*

7 Conclusions

In this paper, we propose and estimate a structural model of location and pricing decisions of gasoline stations in the Singapore market. Our location model, the first of its kind and the first to be estimated for gasoline markets, is built on the premise that the Singapore government determines optimal retail locations for gasoline stations on the basis of maximizing social welfare of Singapore residents by minimizing their travel costs. Our conditional pricing model is built on the premise of Bertrand competition between firms, where the firm is defined as either a gasoline station or a retail chain.

By estimating our proposed location model using empirical data on actual geographic locations of gasoline stations, we are able to quantify the explicit dependence of local potential gasoline demand on the following local demographic characteristics of the neighborhood: population, median income, number of cars, proximity to airport, downtown and highways. Using the estimated category-level demand at each local neighborhood in Singapore as an input, we then estimate our proposed pricing model using empirical data on actual prices of gasoline at various stations. We find retail margins for gasoline to be about 1-2%, and that market share for a gasoline station is negatively influenced by the price of gasoline, and positively influenced by station characteristics such as the number of pumps, availability of pay-at-pump etc.

We use our estimates to perform several policy experiments relating to exit and entry of gasoline stations. More generally, our estimation methodology and results can be used to answer counterfactual questions of interest both to the Singapore government and to gasoline retailers in Singapore. For example, our results would facilitate the planning of future locations for gasoline stations in Singapore. Furthermore, our methodology can be used to throw light on how the nature of competition between gasoline stations would change after such new locations are available for bidding by gasoline retailers.

References

Daskin, M.S. (1995). Network and Discrete Location, John Wiley and Sons: New York.

Davis, P. (2001). Spatial Competition in Retail Markets: Movie Theaters, Working paper, MIT Sloan School of Management.

D'Aspremont, C., Gabszewics, J., Thisse, J.F. (1979). On Hotelling's Stability in Competition, Econometrica, 17, 1145-1151.

Hotelling, H. (1929). Stability in Competition, Economic Journal, 39, 153, 41-57.

Iyer, G.K., Seetharaman, P.B. (2003a). To Price Discriminate or Not: Product Choice and the Selection Bias Problem, Quantitative Marketing and Economics, 1, 2, 155-178.

Iyer, G.K., Seetharaman, P.B. (2003b). Consumer Heterogeneity and Competition: Theory and Empirical Evidence from Retail Gasoline Markets, Working paper, Walter A. Haas School of Business, University of California at Berkeley.

Manuszak, M.D. (1999). Firm Conduct in the Hawaiian Petroleum Industry, Working paper, Graduate School of Industrial Organization, Carnegie Mellon University, Pittsburgh.

McManus, B. (2003). Nonlinear Pricing in an Oligopoly Market: The Case of Specialty Coffee, Working paper, John M. Olin School of Business, Washington University, St. Louis.

McFadden, D.L. (1974). The Measurement of Urban Travel Demand, Journal of Public Economics, 3, 4, 303-328.

Nelder, J.A., Mead, R. (1965). A Simplex Method for Function Minimization, Computational Journal, 7, 308-313.

Phibbs, C.S., Luft, H.S. (1995). Correlation of Travel Time on Roads Versus Straight Line Distance, Medical Care Research and Review, 52, 4, 532-542.

Pinkse, J., Slade, M.E., Brett, C. (2002). Spatial Price Competition: A Semiparametric Approach, Econometrica, 70, 3, 1111-1153.

Png, I., Reitman, D. (1994). Service Time Competition, RAND Journal of Economics, 25, 4, 619-634.

Seim, K. (2002). An Empirical Model of Firm Entry with Endogenous Product-Type Choices, Working paper, Graduate School of Business, Stanford University.

Shepard, A. (1991). Price Discrimination and Retail Configuration, Journal of Political Economy, 99, 1, 30-53.

Slade, M.E. (1992). Vancouver's Gasoline-Price Wars: An Empirical Exercise in Uncovering Supergame Strategies, The Review of Economic Studies, 59, 2, 257-276.

Thomadsen, R. (2001). Price Competition in Industries with Geographic Differentiation: The Case of the Hamburger Segment of the Fast Food Industry, Working paper, Graduate School of Business, Columbia University.